Y-branch optical coupler monolithically integrated with DFB Quantum Cascade lasers.

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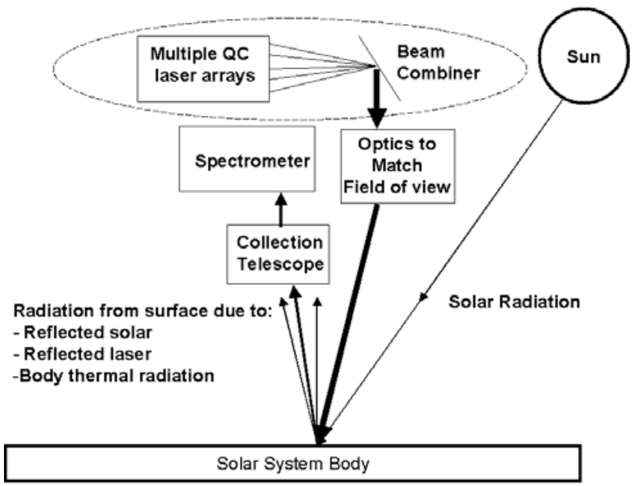
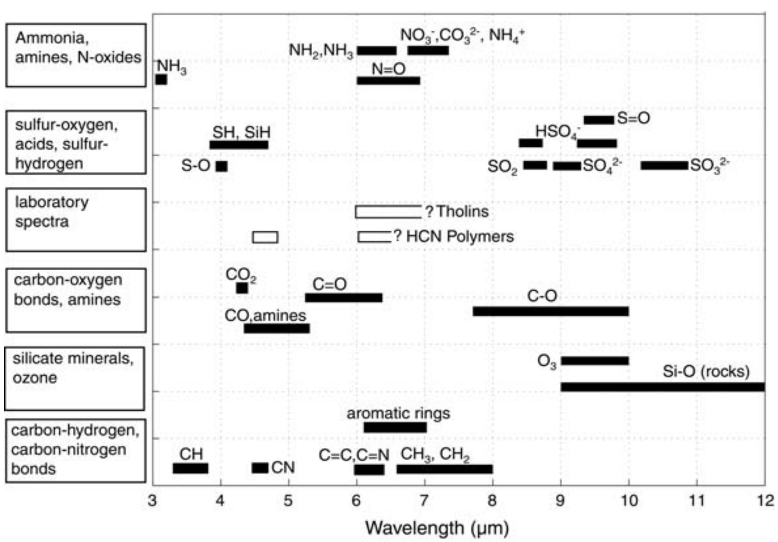
Application for High Capability Instruments

We build mid-infrared lasers to demonstrate a capability to act as the illumination source for conducting active mid-IR reflectance spectroscopy of solid-surfaced objects in the outer Solar System.



- Could be used from on-orbit, aircraft or rover
- Supplements/replaces solar illumination

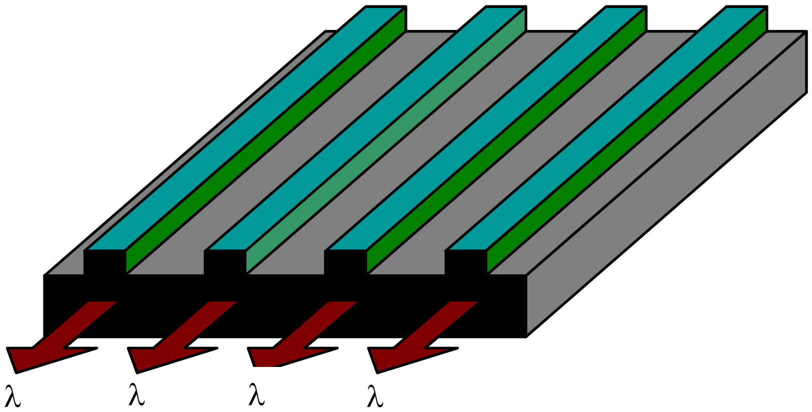
- Wavelength availability has been the Achilles' heel of laser sensing. The use of QC lasers enables the entire IR region (4- 12 microns) to be covered and overcomes this limitation
- Spectral observations in this region, made possible with active illumination, will better enable one to determine the silicate and oxide mineralogy, ice composition, and the composition of organic materials on outer solar system surfaces by being able to observe fundamental absorption bands.



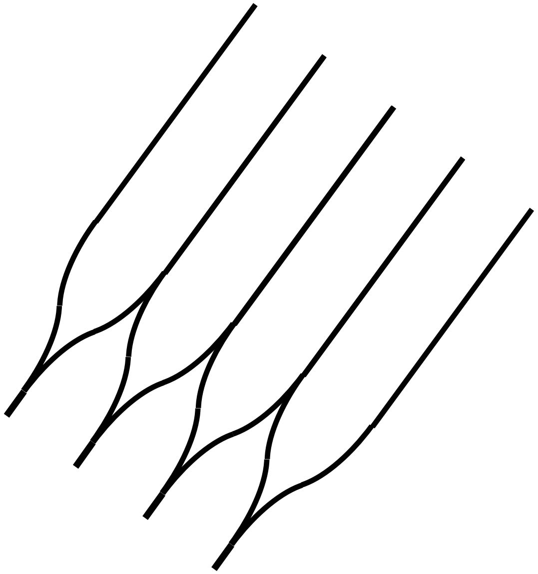
Laser Arrays

The output power of the single-element laser is still not sufficient for many applications. For the proposed remote sensing instruments output power at each wavelength > 2 W

To achieve higher output powers, multi-element QC laser arrays must be developed.

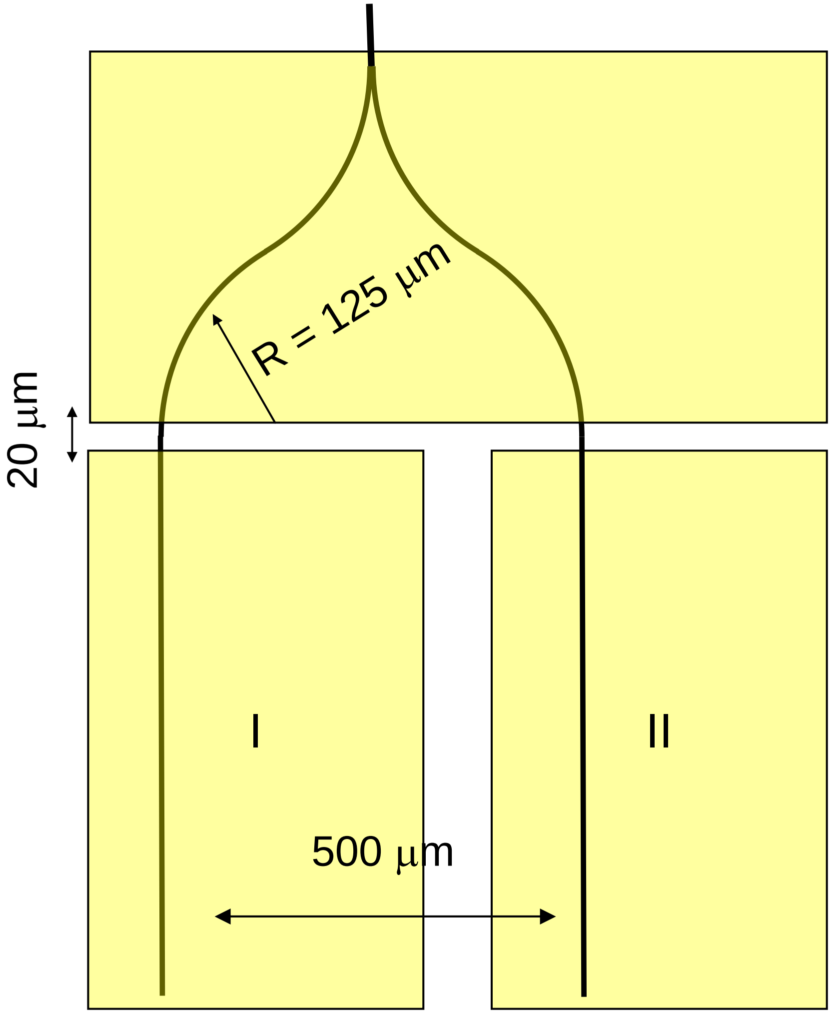


Semiconductor laser array



Y-junction semiconductor laser array

Design Y-branch optical coupler



Bending loss

Bending loss is small if **$(R\Delta/\rho) >> 1$**

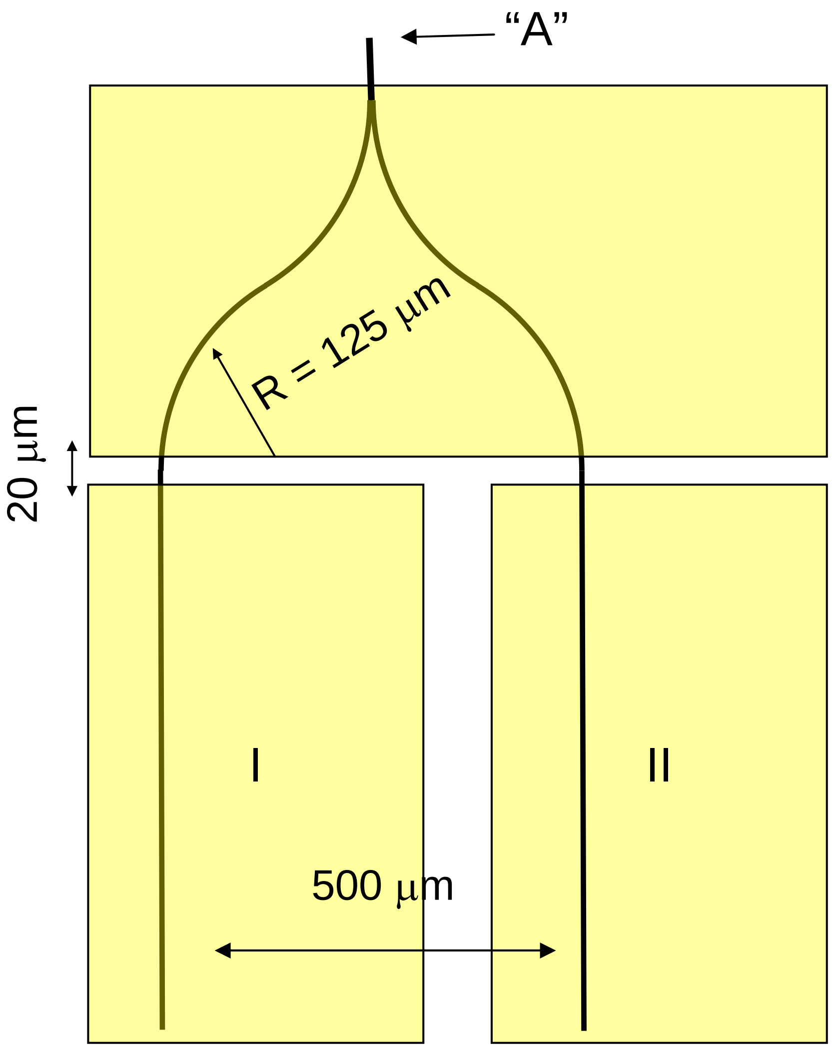
where $\rho \approx 5$ μm is half-width of the waveguide

$\Delta = (n^2_{co} - n^2_{cl}) / n^2_{co} \approx 0.9$

with n_{co} and n_{cl} are refractive indexes of the waveguide core and of the cladding.

Low loss requirements is $R >> 6$ μm that was satisfied in our design with $R = 125$ μm

Design Y-branch optical coupler



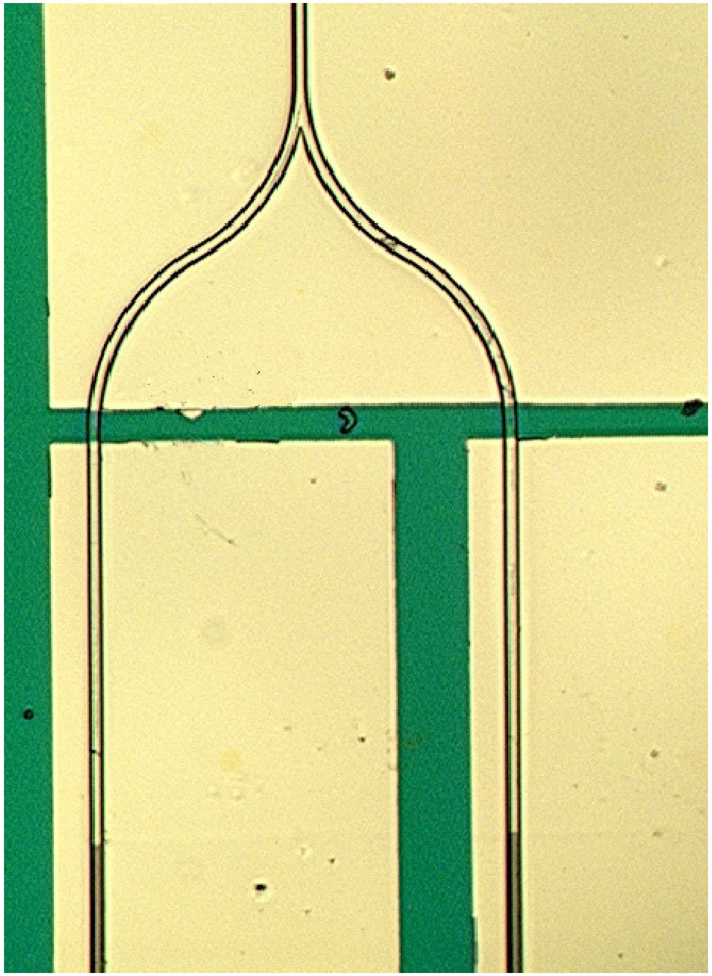
Laser Facets

Use facet "A" or fabricate DFB laser that don't require facets
With DFB lasers - better control of the wavelengths

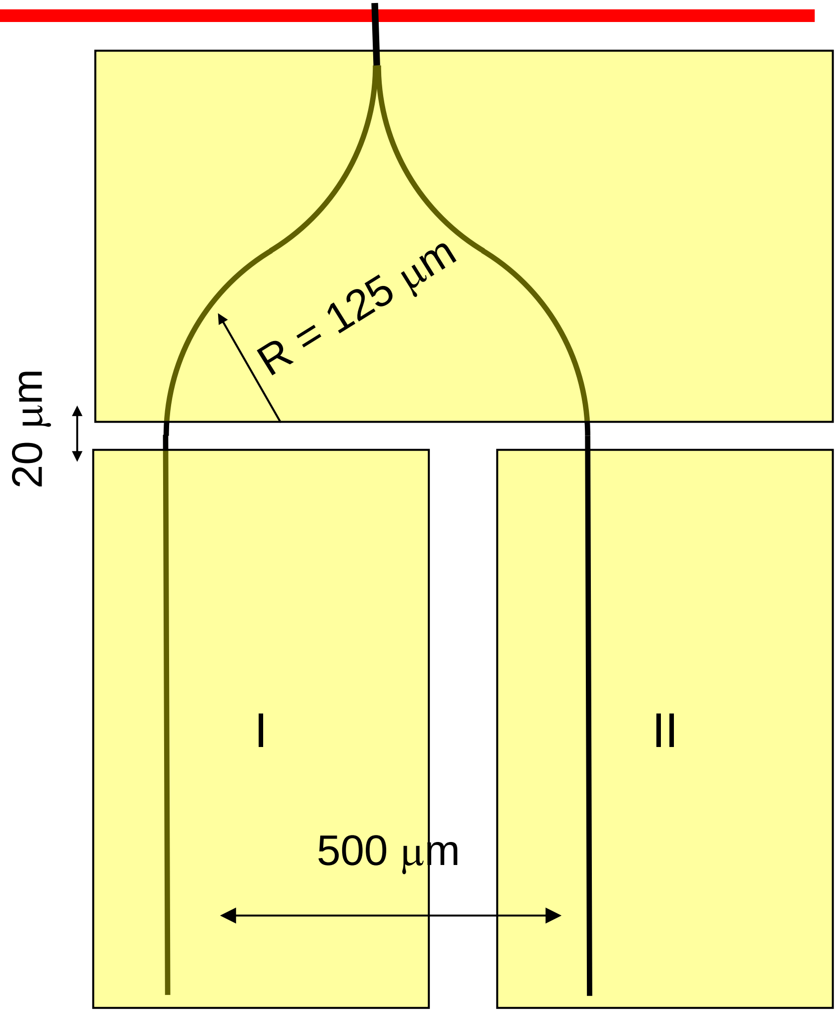
Electrical separation between the Y-branch and the lasers

Resistivity between the Y-branch and the QC laser contact was r_{YL} = 70 Ω, which is much larger than the QC laser differential resistance r_L ~ 1 Ω, and allowed to bias QC lasers and Y-branch independently

Fabrication Y-branch optical coupler

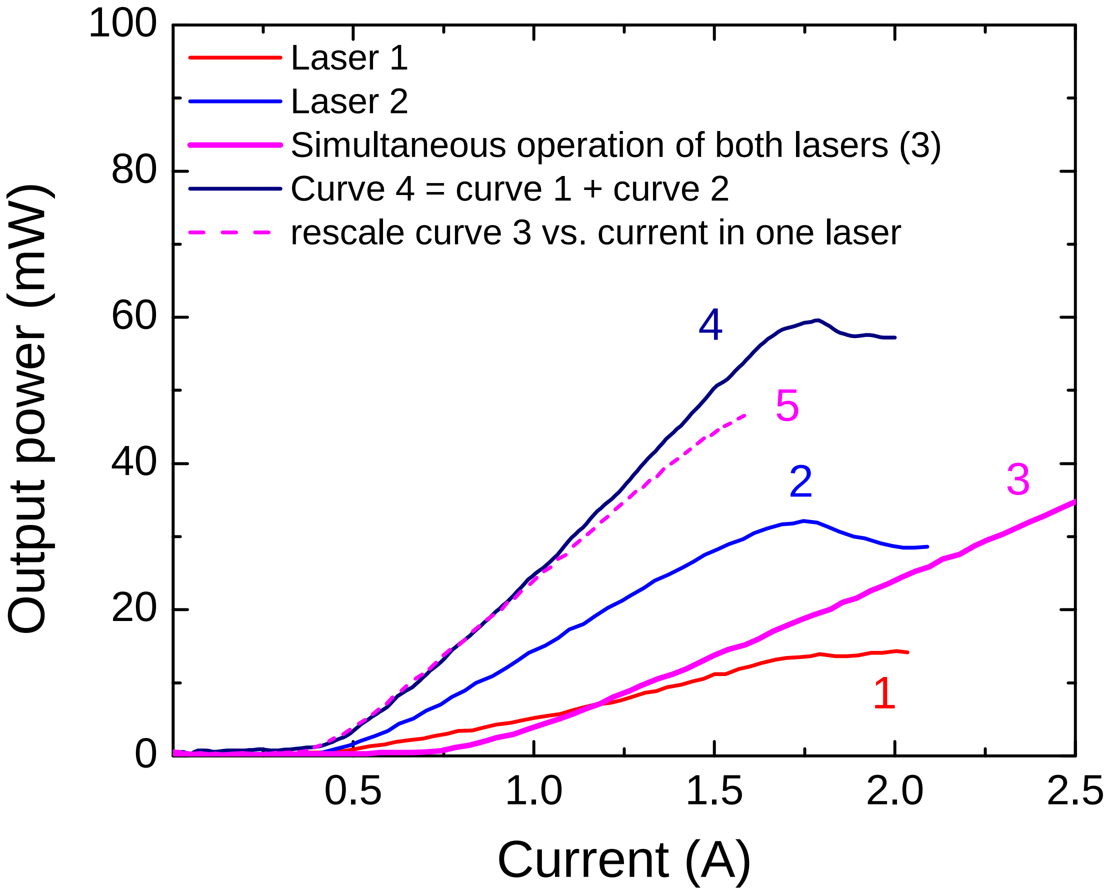


Optical image of fabricated device



Y-branch design

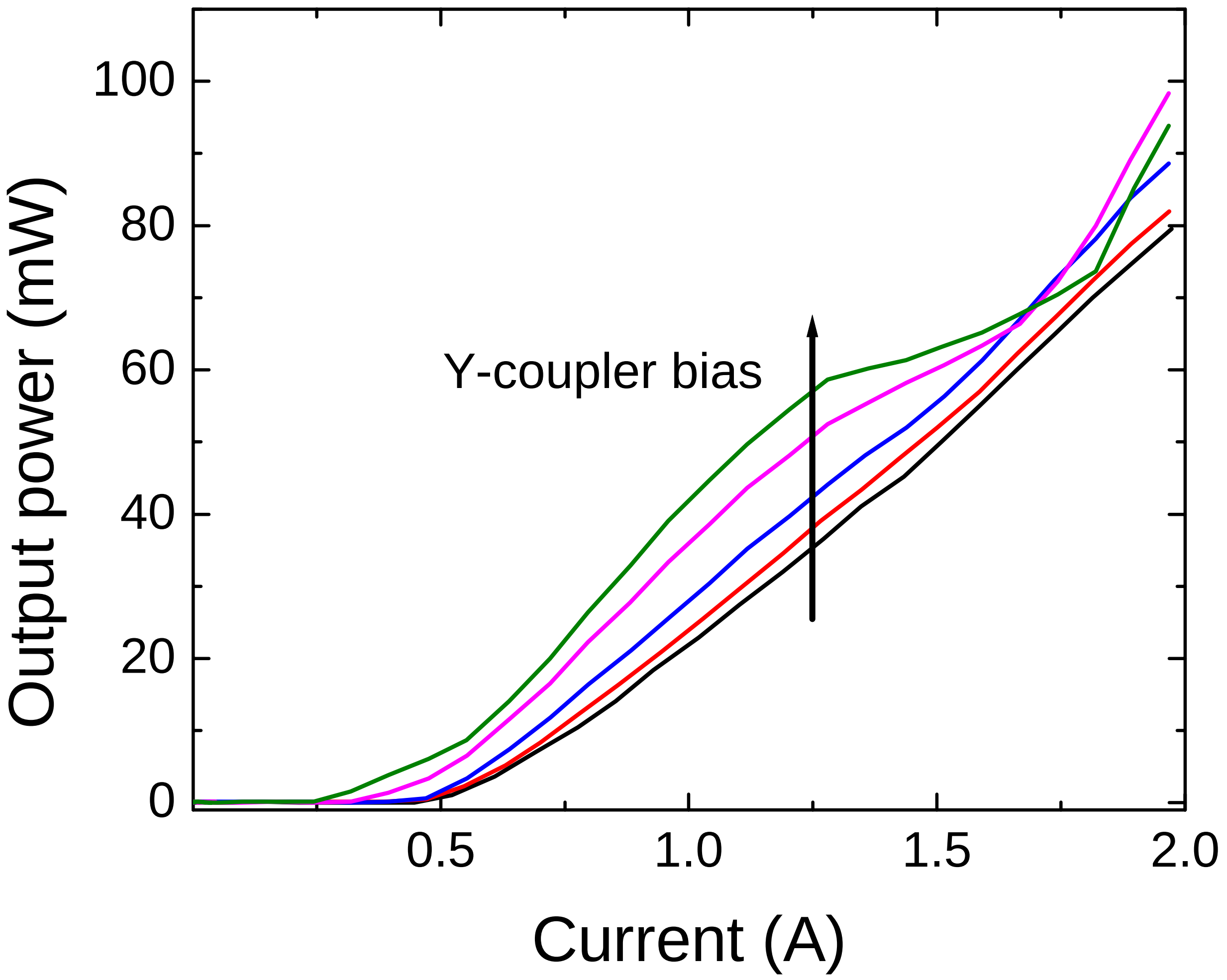
Y-branch operation



T = 77 K, pulsed

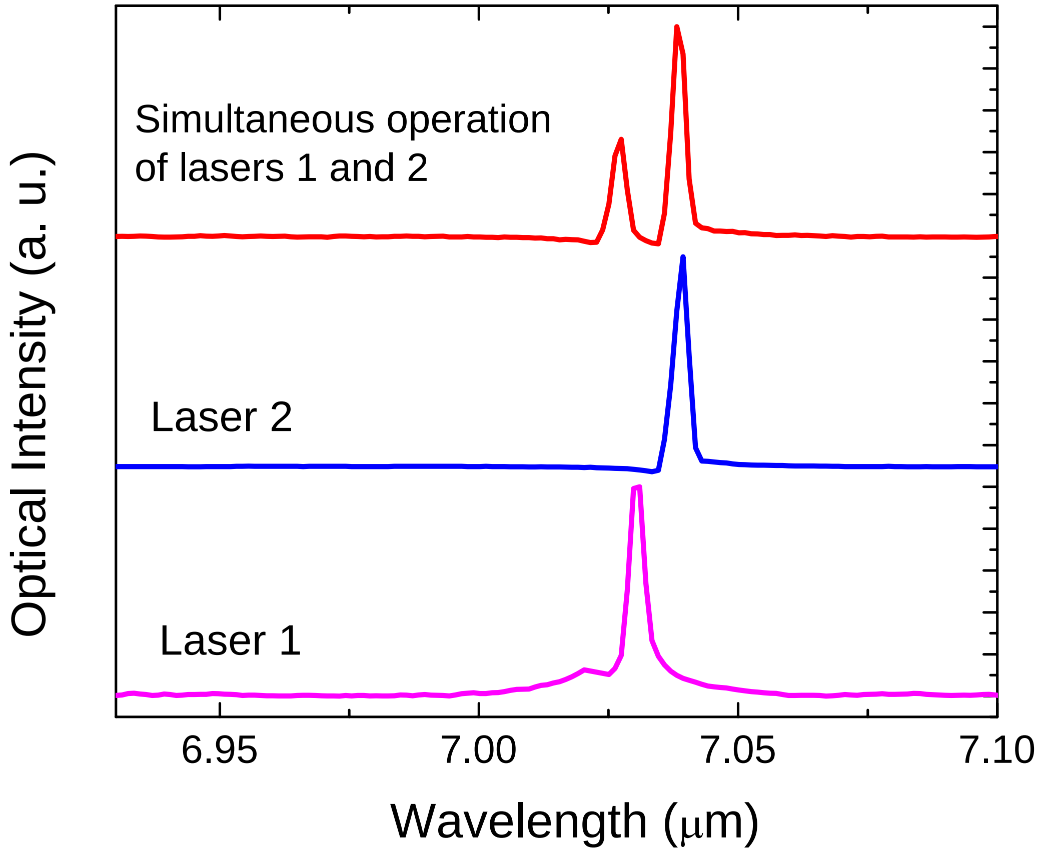
L-I characteristic of the device operating at 77 K in pulsed mode.

Y-branch operation



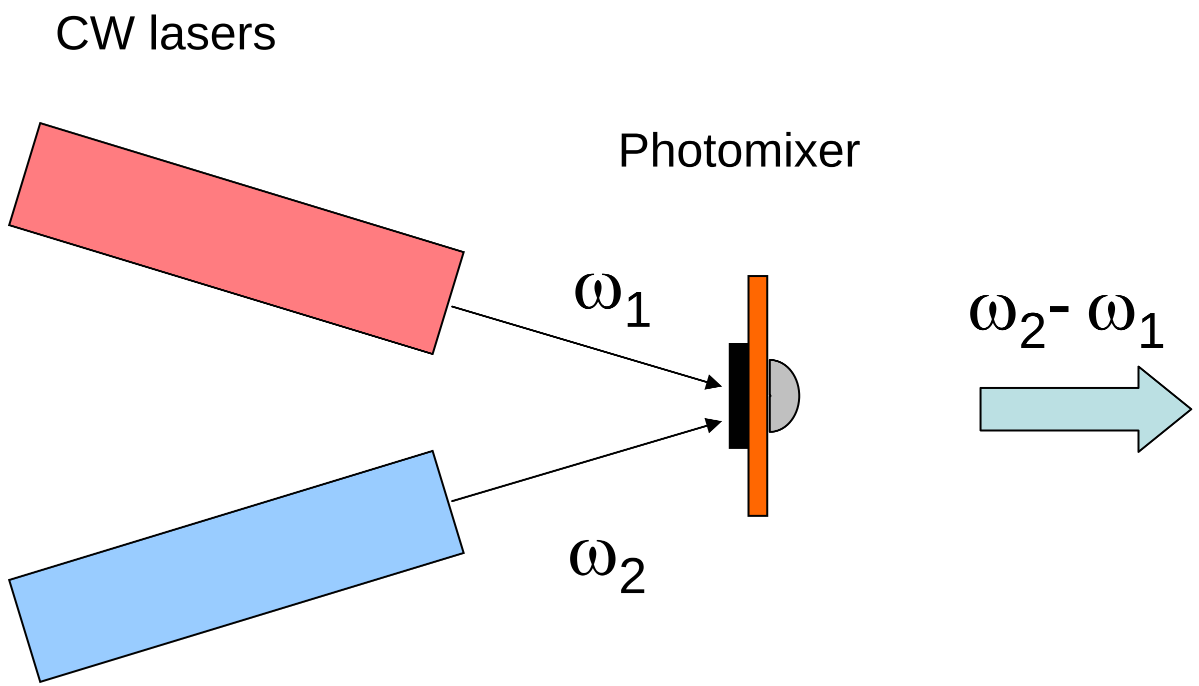
Further amplification of the total output power could be achieved by applying the bias to the Y-branch contact.

Optical spectra



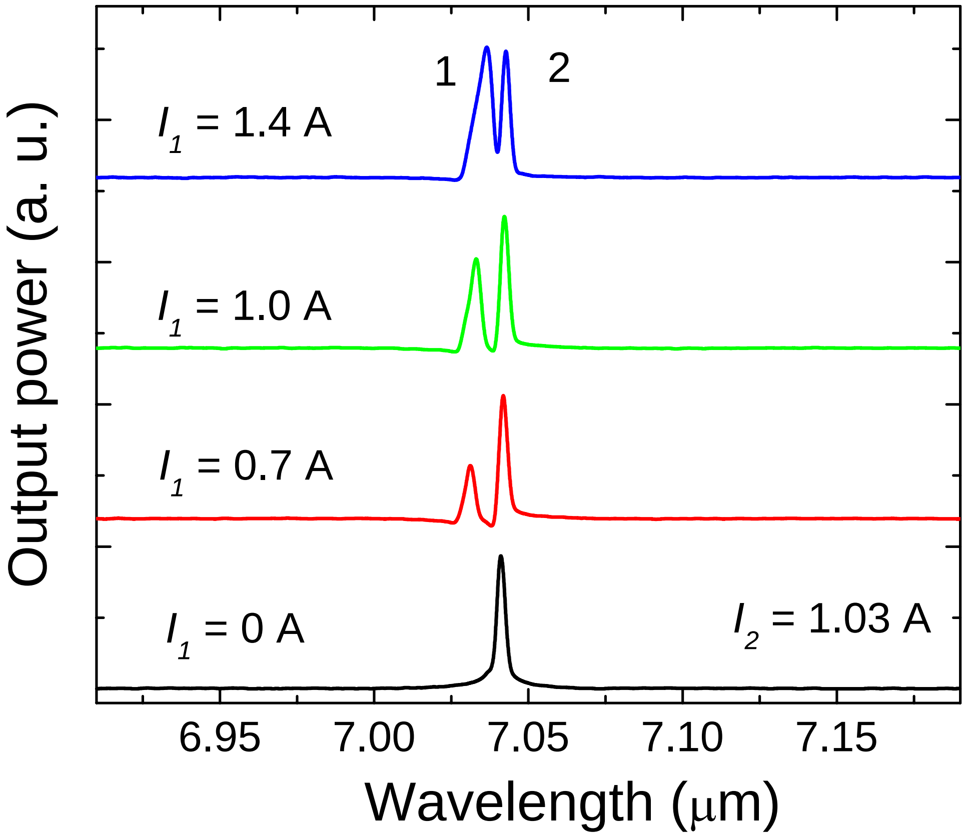
Optical spectra of laser 2 operating
independently and optical spectrum under simultaneous operation of both lasers

Application of Y-branch : Photomixing



Generation of GHz and THz signal by heterodyne frequency mixing

Optical spectra

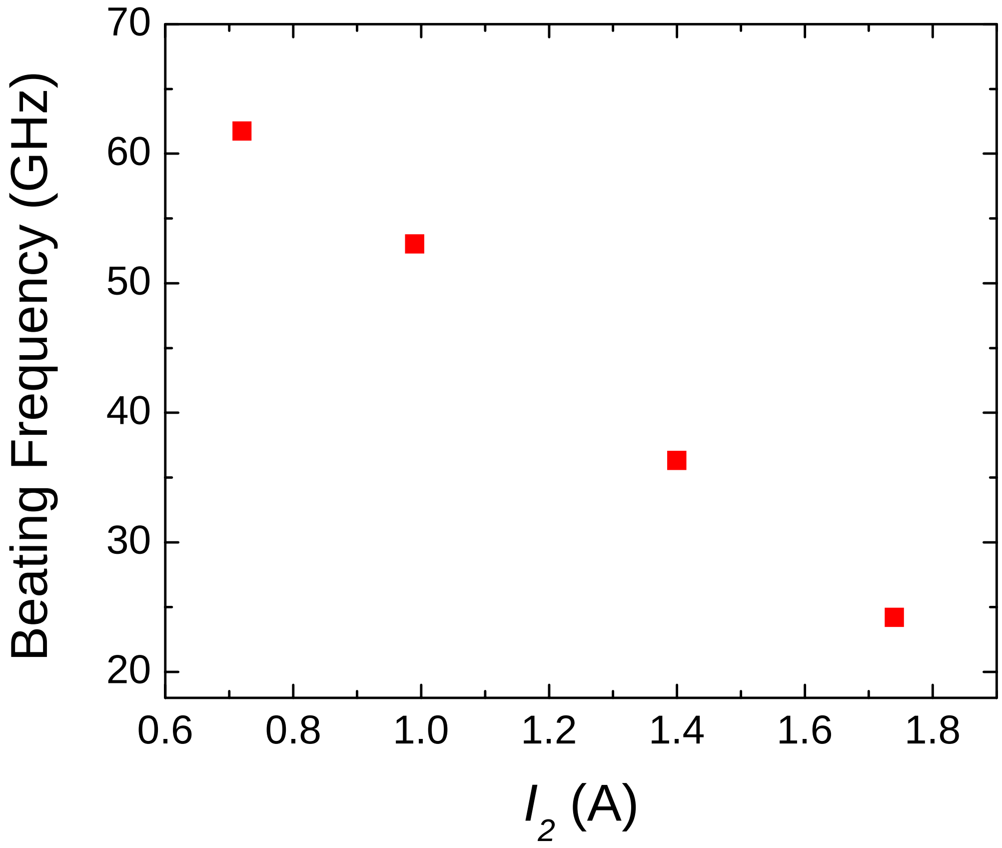


Frequency of the each laser can be varied independently by changing the laser bias.

That shifts the beating frequency

Optical spectrum under simultaneous operation of both lasers, when each laser is controlled independently

Beating Frequency



It is possible to achieve a higher beating frequencies in this device by increasing the waveguide ridge difference and/or employing DFB grating of different periods

Beating frequency vs. driving of laser 1

Conclusion and further work

Y-branch optical coupler for DFB QCL

- Demonstrated operation in the pulsed mode
- Combined output of both lasers
- *Achieve CW operation*
- *Realize Y-junction arrays and increase output power*

Laser combining for photomixing

- Combine the frequency-offset DFB lasers
- Achieve tuning of the beating frequency
- *Realize operation in CW mode*
- *Measure frequency beating with high speed QWIP detectors*
- *Demonstrate photomixing*